REMOTE SENSING IN PEAT SURVEY. CONTRIBUTION TO SOIL MAPPING OF CENTRAL KALIMANTAN PROVINCE USING COMPUTER ANALYSIS OF LANDSAT DATA.

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A B S T R A C T

For soil and peat surveys, the authors used both conventional air-photographs and Landsat imagery.

Landsat data have been used in form of photographs at various scales, of colored combinations of the different channels and of graphics processed by a Honeywell Bull C II Mini 6 computer and a Benson tracing table, using a methodology elaborated by the ORSTOM Remote Sensing Labs.

The tested areas are located in the equatorial Low-lands of Central Kalimantan Province ; and largely covered by forest vegetation.

Practically the authors select several well known test zones of approximately a square kilometer.

The different areas are defined in terms of Landsat lines and columns in order to provide the computer with the limits in which it has to work in each case.

Each test area has been characterized in terms of reflections for each radiometric channel.

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With this technique the authors have tested numerous physiographic units like :

- Forest on swamps and peat.
- Well drained dipterocarp forests.
- River flat forests on stream levees.
- The shifting cultivation areas, on various types of soils.
- Forests on tropical podzols, etc,...

This process allows to single out the low land forests on peat, and it is possible in this way to delimit, in principle, very easily, the peat areas.

Unfortunaltely all this is only valid in countries where the ecological environment has only been slightly disturbed by human activities, and this is not fully the case in Central Kalimantan Province.

But the strongest limitation to this methodology comes from the very bad quality of all satellite pictures covering Central Kalimantan Province : Those with less than 70% of cloud cover are exceptional.

INTRODUCTION

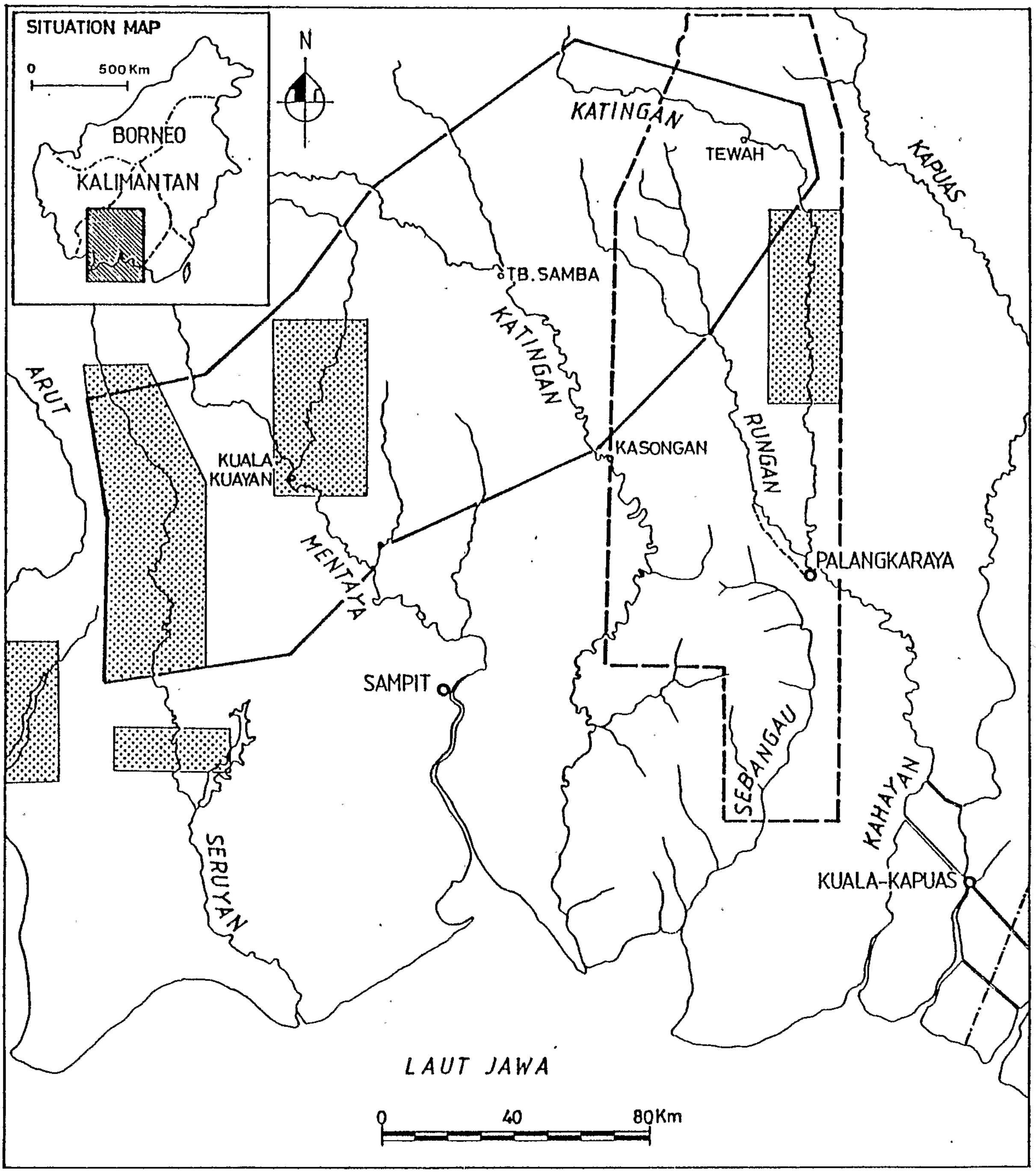
Since 1979 Indonesian and ORSTOM scientists, within the framework of cooperation between France and the Indonesian Department of Transmigration, have worked out soil maps covering more than 2 millions hectares in Central Kalimantan Province. Up to 1983 this survey has been done with a almost total lack of air photographs and the maps were elaborated with satellite documents, generally of poor quality, and field checking. After 1983, air photographs have been available.

SITUATION AND CLIMATE OF THE AREA

The surveyed area is situated in the Central Kalimantan Province between the footslopes of the Schwaner mountains and the sandy and peaty coastal plain of PALANGKA-RAYA - SAMPIT (figure 1).

The totality of the mapped area is subject to a typical equatorial humid low land climate. The principal characteristics of this climate can be summarized as follows :

- Mean annual rainfall between 2100 and 3500 mm.
- Two main rainy periods : March-April and November.
- Average number of days of rainfall : 150 to 180/year.
- Atmospheric humidity superior to 80%.
- Mean annual evaporation between 1100 and 1400 mm.
- Mean annual temperature 27°C.



PIG. 1. LOCALISATION MAP

ORSTOM - TRANSMIGRATION RECONNAISSANSE SURVEY, 1 / 250 000 1979 - 1981.

ORSTOM - UGM - TRANSMIGRATION SOIL SURVEY, 1/100 000 1984-1986.

REMOTE SENSING TEST AREAS.

METHODOLOGY AND MEANS USED

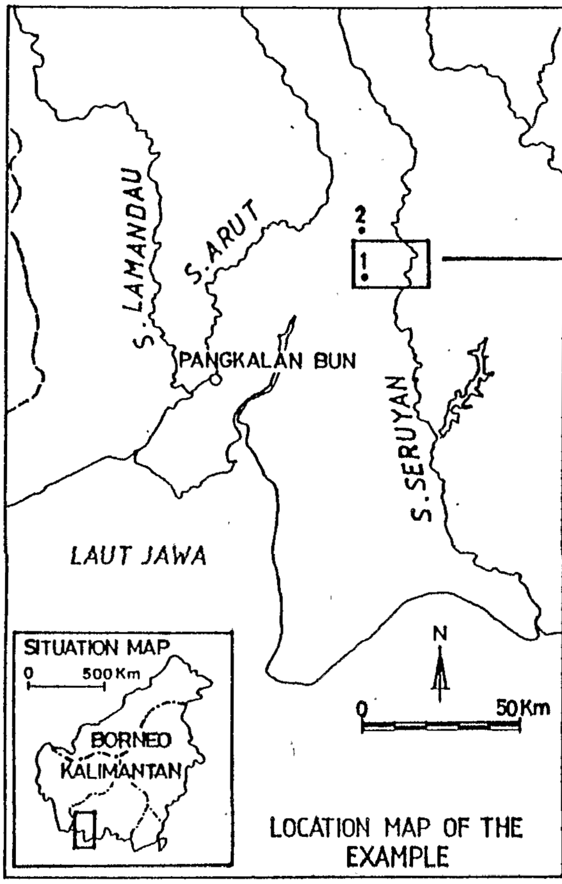
To show what Landsat data can contribute in the mapping of Central Kalimantan, the authors used, after the field checking both conventional air-photographs and Landsat data. Landsat data have been used in form of photographs as well as in form of colored combinations of channels and graphics processed by a computer.

Practically the authors have selected seven physiographic units, well defined through vegetation, soil or water characteristics. Each unit was studied in 5 to 20 different field checked locations : the test areas.

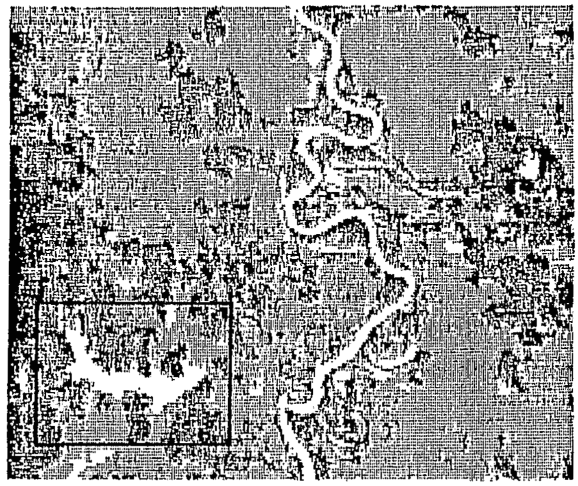
The center of the different test areas is defined in terms of Landsat lines and columns in order to provide the computer with the limits in which it has to work in each case (Figure 2). For each area all pixel values of reflection are asked to the computer, for each radiometric channel, and printed, (Figure 3). The usual width of a test area turns around 1 square km, more or less 350 pixels. Larger areas, each combining two to three physiographic units, have also been studied in a similar way, (Figure 2).

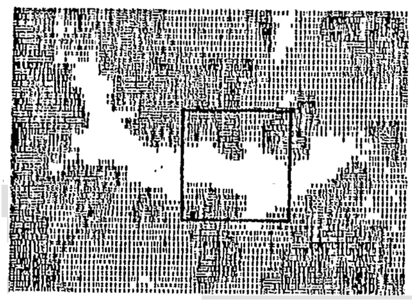
By this method each physiographic unit has been characterized in terms of reflection, in each radiometric channel, (Figure 4). Once the units are defined, different documents can be drawn by a printing table connected to the computer, using the so called "LOTERIE" program which has been elaborated by the ORSTOM Remote Sensing Service, (ORSTOM, 1981). This process allows, through combinations of two or three channels, to single out and to draw physiographic units which are difficult to individualize by a monochannel study.

FIG. 2. INVESTIGATION TECHNIQUE



COMPUTER PROCESSED VISUALISATION





EXAMPLE 1 - BLACK WATER LAKE
SURROUNDED BY FOREST ON PEAT
NASA LANDSAT C.C.T.
SCENE E-10409-02131

22	21	24	25	23	22	23	24	24	24	23	22	15	7	7	7	6	6	7
21	22	23	23	21	22	23	24	23	22	22	17	8	5	5	5	6	11	17
26	21	22	23	23	23	23	23	23	22	20	12	6	6	6	10	16	21	22

FIG. 3

REFLECTION CHARACTERISTICS OF THE PEAT SWAMP FOREST

FROM NASA LANDSAT C.C.T.
SCENE E-10409-02131

BAND 7
19, 20, 21

CANAL:7 coordonnees point central: L= 338 C=2666

740 m.

19	21	21	19	20	21	20	21	20	20	20	21	20
19	19	20	20	20	20	20	20	20	20	20	19	20
20	20	20	20	20	20	21	20	21	21	21	20	20
18	18	19	19	19	19	19	19	20	20	19	19	19
19	20	19	19	19	19	19	19	19	20	20	20	19
21	20	21	20	21	21	23	21	21	21	21	22	22
22	22	21	21	21	21	21	22	21	21	21	21	21
20	20	19	21	21	20	21	20	20	20	21	20	20
21	21	21	21	22	21	20	21	21	20	21	21	20
18	19	19	19	20	20	19	20	20	19	19	20	19
19	19	19	20	19	19	19	19	19	19	19	20	19
20	20	20	20	20	22	21	20	21	21	21	21	20
20	21	20	19	20	20	20	21	21	20	21	21	21

BAND 6
34, 35, 36, 37

CANAL:6 coordonnees point central: L= 338 C=2666

1000 m.

32	37	35	35	37	37	35	35	35	35	37	37	35
36	34	36	36	34	34	34	34	38	36	36	36	34
34	34	34	38	36	34	34	36	36	34	34	34	36
37	37	35	37	37	37	41	39	37	37	39	39	39
36	40	40	34	38	38	38	38	38	38	40	38	38
37	38	38	37	35	38	39	38	38	39	39	38	38
37	39	37	35	37	37	37	37	37	37	37	37	32
36	36	36	36	36	38	40	36	36	36	36	34	38
34	38	38	36	34	36	34	36	36	34	36	36	36
37	37	37	39	39	39	37	39	39	39	37	39	37
38	36	36	33	36	38	38	38	36	36	36	36	38
37	37	38	38	37	37	37	37	37	37	38	39	38
35	37	37	35	35	37	37	37	37	37	37	37	37

BAND 5
16, 17

CANAL:5 coordonnees point central: L= 338 C=2666

16	16	17	17	17	16	16	17	16	17	17	17	17
16	16	17	16	16	17	17	16	16	17	17	17	17
16	18	18	16	16	15	18	16	16	16	18	16	16
16	16	16	18	18	18	18	16	16	18	18	16	16
16	16	16	16	16	16	16	16	16	16	16	16	16
17	16	16	17	17	16	16	16	17	17	17	16	16
17	17	16	17	18	17	17	17	17	18	17	17	17
17	16	17	17	17	16	17	16	16	17	17	16	17
16	18	18	18	16	16	16	15	16	16	16	16	16
18	18	16	18	16	18	16	18	16	16	16	16	16
15	15	15	16	16	16	16	15	16	16	15	15	16
17	16	16	16	16	17	15	16	16	16	16	16	16
17	16	17	17	18	17	17	17	16	17	16	17	17

BAND 4
25, 26, 27

CANAL:4 coordonnees point central: L= 338 C=2666

27	27	25	27	25	25	27	27	27	27	27	27	27
26	26	27	27	27	27	27	27	26	26	27	27	27
24	26	24	26	26	26	26	26	26	26	26	26	26
26	26	26	26	26	26	28	26	26	26	28	28	28
26	26	25	25	26	25	26	25	26	26	26	26	25
28	26	28	26	28	26	26	28	26	28	28	26	28
27	27	27	27	27	27	27	27	27	27	27	25	27
26	27	27	27	27	27	26	26	27	27	27	27	27
26	26	26	26	26	28	26	26	26	26	28	26	26
28	28	26	26	26	28	26	26	28	26	26	26	26
26	26	26	26	26	26	26	26	26	26	26	25	25
26	26	26	26	26	28	26	26	26	26	26	26	26
27	27	27	27	27	27	27	25	25	27	27	27	27

(LOCATION 2. IN Fig. 2.)

THE ANALYSED PHYSIOGRAPHIC UNITS

The following physiographic units have been analysed in terms of reflection for each Landsat channel :

- Two units of upland primary forest.
- The riverine forest.
- The secondary forest of the shifting cultivation area.
- The forest on podzols.
- The forest on peat swamps.
- The river water coming from upland areas.
- The black waters from the podzol and peat areas.

THE UPLAND PRIMARY FOREST

The upland forest covers all the northern part of the surveyed area. This type of forest grows mainly on Oxisols and Ultisols in a large range of topographic situations. Bruning (1969) calls this forest the dipterocarp forest and divides it in several subtypes which are difficult to distinguish by a non botanist. On air photographs one can see evident strong variations in the size and the height of trees ; there are at least two major types in function of the height of the trees :

- The first type, with the highest and biggest trees is usually found in hilly terrain on Andesitic and Dioritic rocks.
- The second type, with a less high canopy, smaller trees and a thicker underwood is mostly located on granitic areas and on tertiary kaolinitic sediments.

In many places transitions can be found between these two types of dipterocarp forest mainly on granodioritic areas.

THE RIVERINE FOREST

We understand under this appelation forests occuring in flat valleys filled with mineral deposits and on river levees not formed by peat. Nevertheless shallow organic deposits may occur locally. The riverine forest can be more or less dry according to the heigh of the river levee. In figure 1 in the KAHAYAN, KATINGAN and RUNGAN valleys, this type of forest is mostly restricted to a hundred meters large strip along the river and shift to a basin swamp forest just behind.

THE SECONDARY FOREST IN THE SHIFTING CULTIVATION AREA

We understand under secondary forest, all stages of forest regrowth after a cultivation cycle until the forest has reached the stage of a healthy old secondary forest of 20 to 30 years old.

The shifting cultivation area with secondary forest can be found along all the rivers, on each side, on several kilometers deep. The secondary forest differs from the primary forest in its floral composition, but in situ, in the forest, it is almost impossible for someone who is not a specialist to differentiate between a true primary forest and a 30 years old healthy secondary forest.

Nevertheless we will see further that it is easy to distinguish even an old healthy secondary forest from the primary forest in the infrared Landsat channels.

THE FOREST ON PODZOL

We give this appelation to the forest occuring on podzolized poor sandy soils. There are, however, at least two major types in function of the topography.

- One type is found on the flattest and lowest part of the "PALANGKA-RAYA" quaternary level on podzols frequently waterlogged through the presence of hard pans. This forest locally changes very gradually into high peat forest.
- Another type of podzol forest is found more inland, on the highest part of the "PALANGKA-RAYA" surface, just before its contact with the tertiary belt. The soils under this forest are giant podzols with a rather good external drainage and rarely waterlogged.

Usually the two types of forest show up markedly on air photographs and can be easily distinguished from others.

THE FOREST ON PEAT SWAMPS

The largest part of the peat areas of Central Kalimantan Province is covered with forest. Like the forest on uplands, the peat swamp forest presents different aspects which can be differentiated on air photographs : It can be a dense forest of rather small trees mainly in the center of large basin swamps, or a higher forest with an irregular canopy and a larger amount of big trees.

This different aspects do not seem so much to lay in the floristic composition but more in the size and the height of the trees. Apparently there is a correlation between these two aspects, the thickness of the peat,and the drainage conditions.

THE PRINCIPAL RESULTS

1. Distinction Primary Forest - Secondary Forets.

These two types of physiographic units can be easily differentiated on all the Landsat imagery of Central Kalimantan. This is the consequence of the very different reflection values of these two units in all the Landsat bands (figure 4) ; this difference is, without any doubt, the visualisation of a strong change in the botanic composition between a primary forest and a secondary one. In this case the Landsat analysis is much more efficient than the human eye and the air photographs.

This is probably the most valuable contribution of Remote Sensing to mapping techniques in Kalimantan ; it can be a very quick, economic and reliable way to follow the progress of the secondary forest and to control its extension.

2. The Characterisation of the Peat Swamp Forest.

The peat swamp forest has an excellent definition in all the Landsat bands, principally in band 5 (figure 3). The reflection values of this units are low, nearly as low as those of the black waters in band 4 and 5. Nevertheless, it is absolutely impossible to distinguish the high canopy from the low canopy peat swamp forest by means of remote sensing though they show up markedly on air photographs.

3. The riverine forest shows in the point of view of Landsat reflection values, an overlap with the secondary forest. In fact the riverine forest can be considered as a kind of secondary forest.

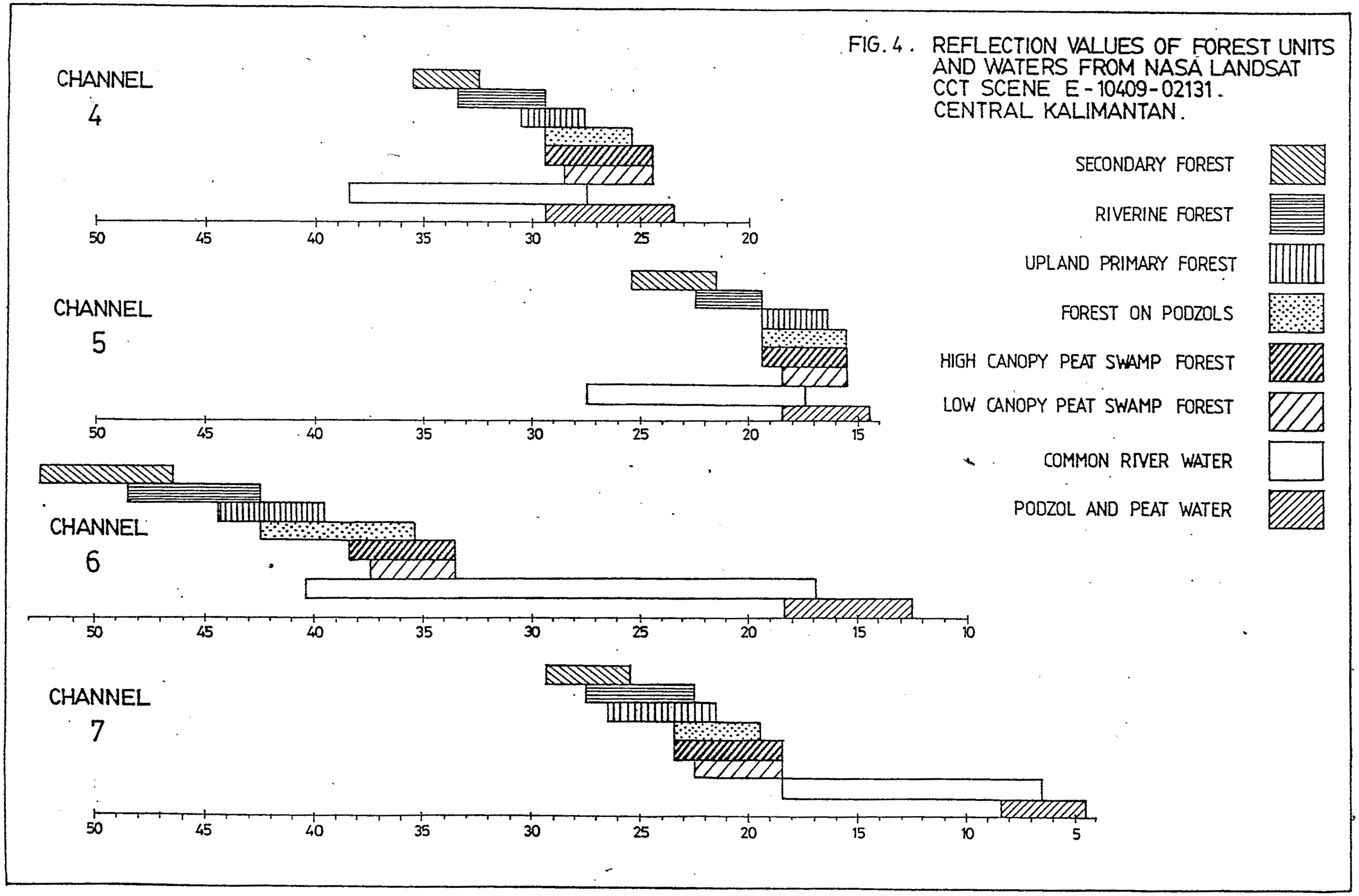


FIG. 4. REFLECTION VALUES OF FOREST UNITS AND WATERS FROM NASA LANDSAT CCT SCENE E-10409-02131. CENTRAL KALIMANTAN.
CHANNEL 4
CHANNEL 5
CHANNEL 6
CHANNEL 7
50
45
40
35
30
25
20
15
10
5
SECONDARY FOREST
RIVERINE FOREST
UPLAND PRIMARY FOREST
FOREST ON PODZOLS
HIGH CANOPY PEAT SWAMP FOREST
LOW CANOPY PEAT SWAMP FOREST
COMMON RIVER WATER
PODZOL AND PEAT WATER

4. The reflections of forests on podzol show in all Landsat bands, a strong overlap with those of the peat swamp forest. Even the forest on well drained, never waterlogged podzols shows Landsat reflections, in all bands, very similar to those of the peat swamp forests, and that is considerably awkward, difficult to overcome.

In most cases, it is only possible to define and to draw, one unit which gathers together all forests on peat swamps and podzols.

5. The characterisation of the two types of upland primary forest.

We have tried in numerous test areas to differentiate the high canopy primary forest from the low canopy primary forest. But remote sensing techniques fail to work in this case.

Even in places where it is possible, in the field, to locate a very sharp limit between these two types of forest, and where the two types show up markedly on air photographs, they can not be differentiated on remote sensing documents ; even in places where the satellite documents are of good quality.

The consequences of this failure are regrettable, while it means also the impossibility to distinguish, through remote sensing techniques, the high productive dipterocarp forest from that of moderate and low productivity ; and the impossibility to distinguish the volcanic belt from the tertiary sedimentary belt.

6. The distinction of "black waters" from upland river waters.

Usually these two types of waters differ markedly in reflection values in the different Landsat channels (figure 4), and even if there is sometimes an overlapping, it is relatively easy to characterize and to draw the two units by means of the "LOTERIE" program.

7. The influence of the atmospheric humidity.

The atmospheric humidity, and its strong variations, on even short distances on a same Landsat scene, is probably the most limiting factor to remote sensing applications in Kalimantan.

Atmospheric humidity, when present, affects the reflection value of all recognized physiographic units, in all radiometric Landsat channels, and shift them from 5 to 20 units towards the higher values.

The consequence of this is that a computer program which works perfectly on a hundred square kilometer test area can be totally inefficient on another area of the same Landsat scene, even a short distance away.

Thus, the strongest trump of the computer technology, which is the possibility to extend a locally tested program to the whole Landsat scene, fails completely to work when applied to Central Kalimantan Landsat data.

CONCLUSIONS

This study shows the support that computer processed Landsat data can bring in environmental mapping : there are very serious limitations. The strongest handicap comes from the always high atmospheric humidity and the very bad quality of all satellite scenes covering Central Kalimantan Province. The study is backed by a large number of ground data, collected during six years, and a set of 17 maps covering more than 25000 square km, publised at the 1/250 000 and 1/100 000 scale.

The computer analysis of Landsat tapes allows the automatic drawing of physiographic units by a program elaborated in the ORSTOM Remote Sensing Section. This methodology permits the characterisation of vegetation units. But as one knows, the limits of physiographic vegetation units are frequently also the limits of soil units, or of ecologic conditions, and it is possible by this way to draw some soil unit limits. But this is only possible in areas where the ecological environment have not been disturbed by human activity ; and that it is only the case in approximately 60% of the mapped area.

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